The Specialized Systems of Scientific Visualization

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The Specialized Systems of Scientific Visualization

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Abstract. In the paper the necessity of development of the scientific visualization specialized systems is shown on examples and the tendencies in methods of specialization are described. The methodology of development of the computer visualization specialized systems is given. The project of interactive visualization system for parallel computations is described.

INTRODUCTION

The scientific visualization was one of the main objectives of using of computer graphics systems since the 60-s' years. The first computer graphics packages contained a significant set of means directed just for representation of computer modeling results.

It is necessary to note two tendencies of visualization systems design and development. On the one hand - developments of universal visualization systems, and on the another - specialization on all directions. The important feature of universal visualization systems is the presence of typical set of views for typical mathematical objects. Thus, it may support the tool for development of specialized visualization. The user task lies in describing of connections between standard views and modeling entities that is necessary to visualize. Universal systems contain some standard set of ("universal") views and techniques of visualization.

The specialized systems facilitate the user's work, and, in case of principally new model objects researching only through these systems using the evident representation about model's nature and particularities features is possible to get. Our experience gives a number of examples of specialized visualization systems using for the analysis and interpretation of the data that is the results of the difficult problems decisions.

A SPECIALIZED SYSTEM FOR VISUALIZATION OF TUBE-LIKE OBJECTS

The tube-like objects are the results of numerical solution of control theory and differential games, where the main element is the value function. Researchers are

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interested in finding such function characteristics degeneration of sections of these tubes, the presence of non-smoothness, so called narrow throats (see Fig. 1) and other tube details. It is impossible to represent these subtle details using universal visualization systems. Only specific information from mathematicians about the nature of mathematical objects had allowed showing them. Features of this system allow investigating singular surfaces in linear differential games and maximal stable bridges [1].

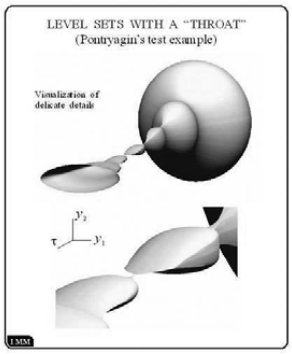

FIGURE 1. **"Narrow throats" in differential games**

VISUALIZATION OF FOUR-DIMENSIONAL INFORMATION SETS

The parallel program for search of reactions speeds at mathematical modelling of chemical processes was developed. Parameters of model are speeds of elementary reactions. After transformations the problem was reduced to finding the quaternaries of speeds of these elementary reactions. The set of all allowable series of speeds is information set, which in this case consists of about one million quaternaries of numbers. Thus, a problem of a finding of these numbers was reduced to a problem of a information set finding.

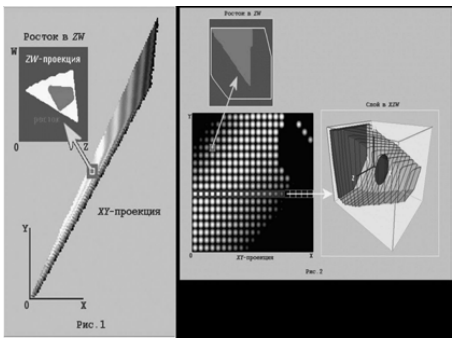

FIGURE 2. View of four-

Studying of a geometrical structure of this set has allowed investigating interrelation of the elementary reactions participating in process of splitting. Particularly, it is necessary to develop visualization methods to investigate local and global characteristics of sets arrangements in four-dimensional space. For analyses of the information about these four-dimensional set it is insufficiently to use only a one known view of multidimensional sets. A battery of visualization methods has been offered be the knowledge of aprioristic sets structure and the visualization goals. After consultations with mathematicians, (potential) users, priority views have been chosen among the suggested views. The complex approach to visualization has been developed. The idea of interaction with the user during the visualization and using of some complex views is a basis of this approach. Thus each view is connected with others. It allows to realize the "navigation" on the set and to analyze all its necessary properties. Thus, during the realization of the system the new approach for visualization of concrete information four-dimensional sets have been offered. The problem of their representation was basically solved [2]. See Fig. 2.

THE SPECIALIZED SYSTEM OF VISUALIZATION FOR ONE PROBLEM OF OPTIMUM CONTROL

The search of reachability sets in one of optimum control problems is a source of the statement of the following problem. A number of reasons, connected with the realization of the algorithm, has led to the fact that the body of computed data make about tens millions, and even billions points in a bitmap-format. The mathematicians would study a general view and an internal structure of the specific problem reachability set. A program complex allowing to do a data filtration not deforming neither external and nor internal object structures has been created. The system allows to display as process of the reachability set constructions and as object in different foreshortenings. The program complex consists of a set of functions to deal with a huge cloud of points and its subsequent visualization. The data are processed on the specialized "visualization pipeline", consisting of such stages as processing initial bitmap-files; lightness computing converting into a voxel format and the creation of structures for scene storage; smoothing of voxel objects; converting into a polygonal format. In the example so-called Lorentz's sphere (See Fig. 3) are considered. After computing of this sphere the volume of an initial file was approximately 6,5 millions points. In a result the graphical object consisting from about 40000 polygons was created. It is obviously, that now computer hardware does not allow to manipulate interactively by millions points objects in contrast to tens thousand polygons. Thus as a result of the specialized system development the volume of the data has considerably decreased with lost-free qualities. It has allowed to study results of numerical research without excessive requirements to hardware resources [3].

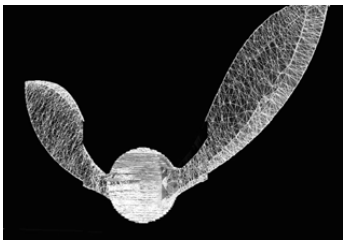

FIGURE 3. Lorentz's sphere.

METHODOLOGY OF SPECIALIZED COMPUTER VISUALIZATION SYSTEMS DEVELOPMENT

Our researches and the realization of concrete systems have enucleated the methodology of the development of the specialized computer visualization systems. First of all techniques of views construction were offered. Among these techniques are visual exaggeration of features due to dependent from ad hoc knowledge about physical (biological information, etc.) and/or mathematical entities of the data; choice of necessary perspective for graphical displays; construction of the special visual objects which are not having accordance to modelling objects, but providing their the analysis and interpretation; application of multiviews, showing different aspects of the investigated phenomenon, creation of views systems, including graphics, animation, spreadsheets and text representations, and also navigation by direct manipulations of visual objects; using in views the natural and familiar figurativeness, and also analogues and "drifting" views; application in visualization systems techniques adopted from a cinema and animated cartoon, and also some virtual reality techniques.

Our procedure of design and development of specialized visualization systems it is possible to describe as some plan to order systems realization. First of all, plan consists of positions describing visualization system design. The plan includes also the sequence questions connected to these positions, and also the analysis of problems arising during the designing process. The basic positions in turn determine a set of roles of design and development process participants.

Among specialists who may participate in the process of design and development of visualization systems there are a potential user, a designer of visualization, a expert in methods of computer graphics and human-computer interaction, and a system programmer. We have to understand thus that in the real project the same people can play different roles.

Among the basic positions in the plan of the specialized visualization systems design and development there are the problem under consideration; the user for whom it is supposed to construct visualization means; the program solving the given problem; figurativeness of visualization and methods of interaction; techniques of graphics generation and rendering; system questions. For each position there are the set of questions which answer have to describe the plan of system realization.

SYSTEM OF INTERACTIVE VISUALIZATION OF PARALLEL COMPUTATION

The developed technique of designing specialized visualization systems is used now on the creation of the specialized visualization systems problems connected with "large" parallel computation (time of the execution - from several hours to several days and more). As concrete examples the problems of mathematical physics are considered. These problems frequently use for solving grid methods.

To begin the system realization the design of visualization was carried out together with the future users. Visualization and the interface metaphors, and also views were developed. The system should evidently map the grid data of large volumes with the opportunity of searching of anomalies in grid structures. A complex view with elements of interaction was developed. In this view the ability to change a lot of parameters is incorporated. Dimension, methods of rendering, set of the interface functions may change. Using of several rendering methods in one view raises appreciable its universality. Opportunities of polygonal graphics allow depicting in details the block structure of a grid, the hierarchy of components and features of its internal construction. The voxel graphics emphasizes applied value of grid problems, mapping not discrete set of points but three-dimensional model as a continuous array of the data.

The system will be capable to visualize rectangular, hexahedral, pyramidal (see Fig. 4) and other structures of a large volume grid - from tens thousand up to hundred millions points. In the last case parallel processing is supposed [4].

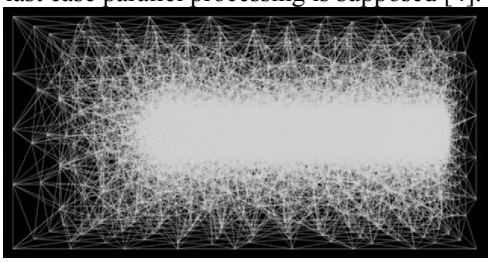

FIGURE 4. The display of the hole grid of 70300 points.

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